

## **CHAPTER 9**

### **EROSION AND SEDIMENT CONTROL**

**22 February 2000**

## Chapter Nine - Erosion And Sediment Control

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## 9.1 Purpose And Scope

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This section provides guidance on measures that should be taken to minimize erosion and control sediment problems associated with land undergoing urban development. Through implementation of the guidelines in this chapter, including development of an erosion and sediment control plan, adverse water quality impacts associated with erosion and sedimentation can be prevented or minimized. These guidelines provide planning boards, governmental bodies, property owners, developers, contractors, consultants and others working with the City of Lincoln with the necessary information for sound development of erosion control plans. Specific topics covered include: fundamentals of erosion and sediment control; key technical principles for controlling erosion and sediment; descriptions of specific erosion and sediment control measures, including use limitations, design criteria, and construction guidelines; and guidelines for development of erosion and sediment control plans, including an example plan.

These guidelines in this section were developed by various local, state and federal agencies. The Lower Platte South Natural Resources District (LPSNRD)<sup>1</sup> (1994) *Erosion and Sediment Control and Stormwater Management Manual* was a key source of information for these guidelines and can be referenced for more detail on topics such as specifications for particular erosion and sediment control measures. Final decisions on erosion and sediment control measures to be used at particular sites should be made by the City of Lincoln, the LPSNRD, and the plan designer in a cooperative working environment.

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## 9.2 Fundamentals Of Erosion And Sediment Control

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### 9.2.1 The Erosion Process

Soil erosion is the process by which the land's surface is worn away by the action of wind, water, ice and gravity. Natural, or geologic, erosion has been occurring at a relatively slow rate since the earth was formed and is a tremendous factor in creating the earth as we know it today. Except for some cases of shoreline and stream erosion, natural erosion occurs at a very slow and uniform rate and remains a vital factor in maintaining environmental balance. Man's activities accelerate the erosion process by loosening and pulverizing soil, making it more susceptible to detachment by natural forces.

Water-generated erosion is unquestionably the most severe type of erosion, particularly in developing areas; it is, therefore, the problem to which this chapter is primarily addressed. Soil erosion by water involves the detachment of particles from the soil mass, transportation by surface runoff, and eventual deposition. Soil particles are detached by the impact of rainfall and the shear force of runoff. Transportation of soil particles is primarily by channelized runoff, although raindrop splash causes some net downslope movement and increases the erosive capability of unchannelized overland flow. Runoff occurs when the rainfall intensity is greater than the soil infiltration rate. Once runoff begins, the quantity and size of material transported is a function of runoff velocity and turbulence. Water-generated erosion can be broken down into the following types:

1. Raindrop erosion is the first effect of a rainstorm on the soil. Raindrop impact dislodges soil particles and splashes them into the air. These detached particles are then vulnerable to the next type of erosion.
2. Sheet erosion is the erosion caused by the shallow flow of water as it runs off the land. These very shallow moving sheets of water are seldom the detaching agent, but the flow transports soil particles which have been detached by raindrop impact and splash. The shallow surface flow rarely moves as a uniform sheet for more than a few feet on land surfaces before concentrating in surface irregularities.
3. Rill erosion is the erosion which develops as the shallow surface flow begins to concentrate in the low spots of the irregular contours of the surface. As the flow changes from the shallow sheet flow to deeper flow in these low areas, the velocity and turbulence of flow increase. The energy of this concentrated flow is able to both detach and transport soil materials. This action begins to cut small channels of its own. Rills are small but well-defined

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<sup>1</sup>Portions of this chapter are modified slightly or copied verbatim from the Lower Platte South Natural Resources District *Manual of Erosion and Sediment Control and Stormwater Management Standards*, 1994.

## Erosion And Sediment Control

channels which are at most only a few inches in depth. They are easily obliterated by harrowing or other surface treatments.

4. Gully erosion occurs as the flow in rills comes together in larger and larger channels. The major difference between gully and rill erosion is a matter of magnitude. Gullies are too large to be repaired with conventional tillage equipment and usually require heavy equipment and special techniques for stabilization.
5. Channel erosion occurs as the volume and velocity of flow causes movement of the stream bed and bank materials. Urban development, typified by removing existing vegetation, increasing the amount of impervious areas and paving tributaries, drastically changes the volume and velocity of flow within a stream, destroying the equilibrium of the stream and causing channel erosion to begin. Common points where erosion occurs are at stream bends and at constrictions, such as those where bridges cross a stream. Erosion may also begin at the point where a storm drain or culvert discharges into a stream. Repair of eroded streambanks is difficult and costly. Figure 9-1 illustrates the five stages of erosion.

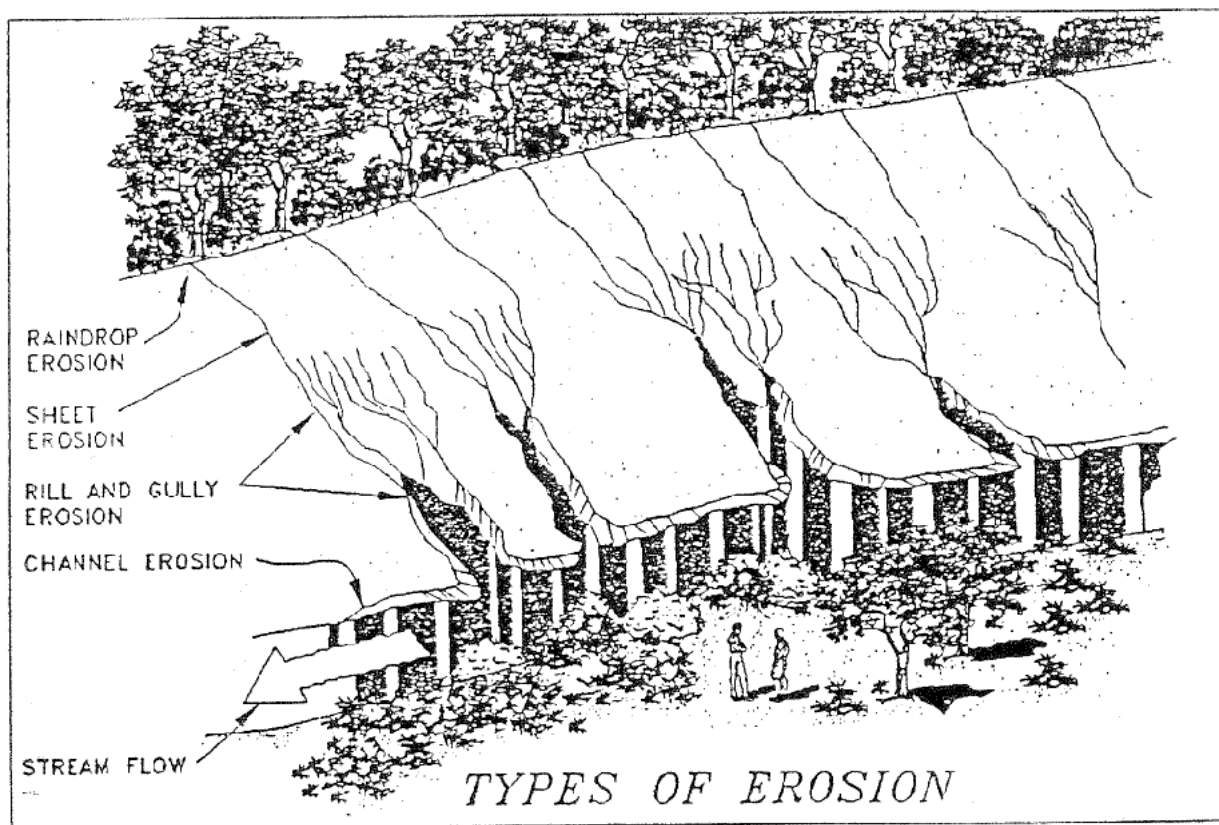


Figure 9-1 Types of Erosion

Source: LPSNRD 1994.

### 9.2.2 Factors Influencing Soil Erosion

The erosion potential of any area is determined by four interrelated principal factors: the characteristics of its soil, its vegetative cover, its topography and its climate. Each of these factors is discussed separately below.

Soil characteristics which influence the potential for erosion by rainfall and runoff are those properties which affect the infiltration capacity of a soil and the resistance of the soil to detachment and being carried away by falling or flowing water. The following four characteristics are important in determining soil erodibility:

1. Soil texture (particle size and gradation)
  2. Percentage of organic matter
  3. Soil structure
  4. Soil permeability
- Soil texture refers to the sizes and proportions of the particles making up a particular soil. Sand, silt, and clay are the three major classes of soil particles. Soils high in sand content are said to be coarse-textured. Because water readily infiltrates into sandy soils, the runoff, and consequently the erosion potential, is relatively low. Soils with a high content of silts and clays are said to be fine-textured or heavy. Clay, because of its stickiness, binds soil particles together and makes a soil resistant to erosion. However, once the fine particles are eroded by heavy rain or fast flowing water, they will travel great distances before settling. Even with the sediment control measures described in this manual, it is extremely difficult to remove clay particles from flowing water. Typically, particles of clay and fine silt will settle in a large, calm water body, such as a bay, lake, or reservoir, at the bottom of a watershed. Thus, silty and clayey soils are frequently the worst water polluters. Soils that are high in silt and fine sand and low in clay and organic matter are generally the most erodible. Well-drained sandy and rocky soils are the least erodible.
  - Organic matter consists of plant and animal litter in various stages of decomposition. Organic matter improves soil structure and increases permeability, water-holding capacity, and soil fertility. Organic matter in an undisturbed soil or in a mulch covering a disturbed site reduces runoff and, consequently, erosion potential. Mulch on the surface also reduces the erosive impact of raindrops.
  - Soil structure is the arrangement of soil particles into aggregates. A granular structure is the most desirable one. Soil structure affects the soil's ability to absorb water. When the soil surface is compacted or crusted, water tends to run off rather than infiltrate. Erosion hazard increases with increased runoff. Loose, granular soils absorb and retain water, which reduces runoff and encourages plant growth.
  - Soil permeability refers to the ability of the soil to allow air and water to move through the soil. Soil texture and structure and organic matter all contribute to permeability. Soils with high permeability produce less runoff at a lower rate than soils with low permeability, which minimizes erosion potential. The higher water content of a permeable soil is favorable for plant growth, although it may reduce slope stability in some situations.

Vegetative cover plays an extremely important role in controlling erosion, providing the following benefits:

1. Shielding the soil surface from raindrop impact
2. Providing root systems that hold soil particles in place
3. Maintaining the soil's capacity to absorb water
4. Slowing the velocity of runoff
5. Removing subsurface water between rainfalls through the process of evapotranspiration

By limiting and staging the removal of existing vegetation and by decreasing the area and duration of exposure, soil erosion and sedimentation can be significantly reduced during construction. Special consideration should be given to the maintenance of existing vegetative cover on areas of high erosion potential such as moderately to highly erodible soils, steep slopes, drainageways, and the banks of streams.

Topography, including the size, shape, and slope characteristics of a watershed, influences the amount and rate of runoff. As both slope length and gradient increase, the rate of runoff increases and the potential for erosion is magnified. The

shape of a slope also has a major bearing on erosion potential. The base of a slope is more susceptible to erosion than the top because runoff has more momentum and is more concentrated as it approaches the base. Slope orientation can also be a factor in determining erosion potential. For example, a slope that faces south and contains droughty soils may have such poor growing conditions that vegetative cover can be difficult to re-establish. Conversely, northern exposures tend to be cooler and more moist, but they also receive less sun, which results in slower plant growth.

Climate characteristics, such as precipitation patterns and temperature, influence runoff and susceptibility of soils to erosion. The frequency, intensity, and duration of rainfall are fundamental factors in determining the amounts of runoff produced in a given area. As both the volume and velocity of runoff increase, the capacity of runoff to detach and transport soil particles also increases. Where storms are frequent, intense, or of long duration, erosion risks are high. Seasonal changes in temperature, as well as variations in rainfall, help to define the high erosion risk period of the year. When precipitation falls as snow, no erosion will take place. However, when the temperature rises, melting snow adds to runoff, increasing erosion hazards. When the ground is still partially frozen, its absorptive capacity is reduced. Frozen soils are relatively erosion resistant; however, soils with high moisture content are subject to uplift action and are usually very easily eroded upon thawing (LPSNRD, 1994).

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### 9.3 Technical Principles For Controlling Erosion

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For an erosion and sediment control plan to be effective, it must be developed in the project planning stage and effectively applied during construction. In most cases, the most practical method of controlling erosion and the associated production and transport of sediment includes a combination of limited time of soil exposure and judicious selection of erosion control practices and sediment trapping facilities. Basic technical principles that should be followed to maximize effectiveness of erosion and sediment control plans include the following:

1. Plan the development project to fit the particular topography, soils, drainage patterns and natural vegetation to the extent practicable. Areas with steep slopes, erodible soils and soils with severe limitations should be avoided when possible. Development delineated floodplains and other areas subject to flooding should be avoided.
2. Minimize the extent and the duration of soil exposure. The duration of soil exposure can be minimized through construction phasing, prompt revegetation and mulching. Grading should be completed as soon as possible and followed by permanent revegetation. As cut slopes are made and as fill slopes are brought up to grade, these areas should be revegetated. Minimizing grading of large or critical areas during the seasons of maximum erosion potential (April through September) reduces the risk of erosion.
3. Apply erosion control practices to prevent excessive sediment production. Keep soil covered to the extent practicable with temporary or permanent vegetation or mulch. Special grading methods such as roughening a slope on the contour or tracking with a cleated dozer may be used. Other practices include diversion structures to divert surface runoff from exposed soils and grade stabilization structures to control surface water. "Gross" erosion in the form of gullies must be prevented by these water control devices.
4. Apply perimeter control practices to protect the disturbed area from off-site runoff and to prevent sedimentation damage to areas below the construction site. This principle relates to using practices that effectively isolate the construction site from surrounding properties, and especially to controlling sediment once it is produced and preventing its transport from the site. Generally, sediment can be retained by two methods: (a) filtering runoff as it flows through an area and (b) impounding the sediment-laden runoff for a period of time so that the soil particles settle out. Diversions, dikes, sediment traps, vegetative and structural sediment control measures can be used to control sediment. These measures may be temporary or permanent, depending on whether they will remain in use after construction is complete. The best way to control sediment, however, is to prevent erosion.

5. Keep runoff velocities low and retain runoff on the site. The removal of existing vegetative cover and the resulting increase in impermeable surface area during construction will increase both the volume and velocity of runoff. These increases must be taken into account when providing for erosion control. Keeping slope lengths short and gradients low, and preserving natural vegetative cover can keep stormwater velocities low and limit erosion hazards. Runoff from the development should be safely conveyed to a stable outlet using storm drains, diversions, stable waterways or similar measures. Conveyance systems should be designed to withstand the velocities of projected peak discharges. These facilities should be operational as soon as possible.
6. Stabilize disturbed areas immediately after final grade has been attained. Permanent structures, temporary or permanent vegetation, mulch, stabilizing emulsions, or a combination of these measures should be employed as quickly as possible after the land is disturbed. Temporary vegetation and mulches and other control materials can be most effective when it is not practical to establish permanent vegetation or until permanent vegetation is established. Such temporary measures should be employed immediately after rough grading is completed if a delay is anticipated in obtaining finished grade. The finished slope of a cut or fill should be designed to be stable and easily maintained. Stabilize roadways, parking areas and paved areas with a gravel sub-base whenever possible.
7. Implement a thorough maintenance and follow-up program. This last principle is vital to the success of the six other principles. A site cannot be effectively controlled without thorough, periodic checks of the erosion and sediment control practices. These practices must be maintained just as construction equipment must be maintained and material checked and inventoried. An example of applying this principle would be to start a routine "end of day check" to make sure that all control practices are working properly.

## 9.4 General Guidelines For Controlling Erosion

The following is a discussion of the general guidelines which shall be considered in developing an erosion and sediment control plan.

### 9.4.1 Stabilization

Soil stabilization refers to measures which protect soil from the erosive forces of raindrop impact and flowing water. Applicable practices include temporary erosion control materials, vegetative establishment, mulching and the early application of a gravel base on areas to be paved. Soil stabilization measures should be selected to be appropriate for the time of year, site conditions and estimated duration of use.

Permanent or temporary stabilization shall be completed within seven (7) calendar days to the surface of all perimeter sediment controls, topsoil stockpiles, and any other disturbed or graded areas on the project site which are not being used for material storage, or on which actual earth moving activities are being performed.

Soil stockpiles should be stabilized or protected with sediment trapping measures to prevent soil loss.

### 9.4.2 Permanent Vegetation

A permanent vegetative cover shall be established on denuded areas not otherwise permanently stabilized.

### 9.4.3 Protection Of Adjacent Property

Properties adjacent to the site of a land disturbance shall be protected from sediment deposition. This may be accomplished by preserving a well-vegetated buffer strip around the lower perimeter of the land disturbance, by installing perimeter controls such as sediment barriers, filters or dikes, or sediment basins, or by a combination of such measures.

### 9.4.4 Timing

Sediment basins and traps, perimeter dikes, sediment barriers and other measures intended to trap sediment on-site

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shall be constructed as a first step in grading and be made functional before upslope land disturbance takes place. Earthen structures such as dams, dikes and diversions shall be seeded and mulched within 7 days of installation.

### 9.4.5 Sediment Basins

Stormwater runoff from drainage areas with 5 acres or greater disturbed area shall pass through a sediment basin or other suitable sediment trapping facility. Sediment basins are more cost-effective when most of the area draining to the basin is disturbed area, since they must be sized based on total contributing area.

### 9.4.6 Cut And Fill Slopes

Cut and fill slopes shall be designed and constructed in a manner which will minimize erosion. Consideration shall be given to the length and steepness of the slope, the soil type, upslope drainage area, groundwater conditions and other applicable factors. The following guidelines are provided to aid site planners and plan reviewers in developing an adequate design:

- Roughened soil surfaces are generally preferred to smooth surfaces on slopes.
- Diversions shall be constructed at the top of long steep slopes which have significant drainage areas above the slope. Diversions or terraces may also be used to reduce slope length.
- Concentrated stormwater shall not be allowed to flow down cut or fill slopes unless contained within an adequate temporary or permanent channel, flume or slope drain structure.
- Wherever a slope face crosses a water seepage plane which endangers the stability of the slope, adequate subsurface drainage or other protection shall be provided.

### 9.4.7 Waterways And Outlets

All on-site stormwater conveyance channels shall be designed and constructed to withstand the expected velocity of flow from a 2-year frequency storm with minimum erosion. Stabilization adequate to minimize erosion shall also be provided at the outlets of all pipes and paved channels.

### 9.4.8 Inlet Protection

All storm drain inlets which are made operable during construction should be protected so that sediment-laden water will not enter the conveyance system without first being filtered or otherwise treated to remove sediment.

### 9.4.9 Crossing Watercourses

Construction vehicles should be kept out of watercourses to the extent possible. Where in-channel work is necessary, precautions shall be taken to stabilize the work area during construction to minimize erosion. The channel (including bed and banks) shall be restabilized as soon as in-channel work is completed.

Where an active (wet) watercourse must be crossed by construction vehicles regularly during construction, a temporary stream crossing shall be provided.

All necessary permits such as construction permits, excavation permits, Floodplain Development permits, Clean Water Act Section 404 permits, and others shall be obtained.

### 9.4.10 Disposition Of Measures

All temporary erosion and sediment control measures shall be disposed of within 30 days after final site stabilization is achieved or after the temporary measures are no longer needed. Trapped sediment and other disturbed soil areas resulting from the disposition of temporary measures shall be permanently stabilized to prevent further erosion and sedimentation.



#### 9.4.11 Maintenance

All temporary and permanent erosion and sediment control practices shall be maintained and repaired as needed to ensure continued performance of their intended function.

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## 9.5 Best Management Practice Selection

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This section provides a decision-making process that can be used to select best management practices (BMPs) to control erosion and sedimentation.

### 9.5.1 Steps In Selection Of Control Measures

Step 1. Identify Control Method(s) - On any construction site the objective in erosion and sediment control is to prevent off-site sedimentation damage. Three basic methods are used to control sediment transport from construction sites: runoff control, soil stabilization, and sediment control. Controlling erosion (runoff control and soil stabilization) should be the first line of defense. Controlling erosion is effective for small disturbed areas such as single lots or small areas of a development that do not drain to a sediment trapping facility. Sediment trapping facilities should be used on large developments where mass grading is planned, where it is impossible or impractical to control erosion, and where sediment particles are relatively large. Runoff control and soil stabilization should be used together where soil properties and topography of the site make the design of sediment trapping facilities impractical. Cost-effective erosion and sediment control typically includes a combination of vegetative and structural erosion and sedimentation control measures.

Step 2. Identify Problem Areas - Potential erosion and sediment control problem areas should be identified. Areas where erosion is to be controlled will usually fall into categories of slopes, graded areas or drainage ways. Slopes include graded rights-of-way, stockpile areas, and all cut and fill slopes. Graded areas include all stripped areas other than slopes. Drainage ways are areas where concentrations of water flow naturally or artificially, and the potential for gully erosion is high.

Step 3. Identify Required Strategy - The third step in erosion and sediment control planning is to develop a strategy that can be taken to solve the problem. For example, if there is a cut slope to be protected from erosion, the strategies may include protecting the ground surface, diverting water from the slope or shortening the slope. Any combination of the above can be used. If no rainfall except that which falls on the slope has the potential to cause erosion and if the slope is relatively short, protecting the soil surface is often all that is required to solve the problem.

Step 4. Select Specific Control Measures - The final step in erosion and sediment control planning can be accomplished by selecting and adapting specific control measures that accomplish the strategy developed in Step 3. From descriptions given on the matrix in Figure 9-2, the measure which is most economical, practical, efficient, and adaptable to the site should be chosen. Once the specific control measure has been selected, a plan key symbol corresponding to the standard construction specification for that measure found in Section 9.6 can be placed on the erosion and sediment control plan to show where control measures will be used. Items to consider when selecting a final best management practice are as follows:

- **Acceptance** - Look at environmental compatibility, institutional acceptance and visual impact.
- **Cost** - Consider material cost, add-ons, installation and preparation costs. (See the LPSNRD (1994) *Manual of Erosion and Sediment Control and Stormwater Management* for detailed examples on conducting benefit-cost analysis.)
- **Effectiveness** - Compare effectiveness of different BMP's. Use manufacturer specs to compare engineering properties.
- **Installation** - Consider ease of installation and durability once installed.

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- **Vegetation** - Consider compatibility of BMP to foster vegetation.
- **Operation** - Consider maintenance requirements for the various BMPs, and for vegetation any irrigation or fertility requirements.

### 9.5.2 Erosion And Sediment Control Matrix

A matrix showing representative BMPs that are appropriate to use in specific problem areas is provided in Figure 9-2. The intent of this matrix is to facilitate selection of BMPs.

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## 9.6 Best Management Practice Design

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### 9.6.1 Introduction

This section provides a discussion of commonly used erosion and sediment control practices with specific emphasis on use limitations, design details and construction specifications. Please note that this section provides an overview of the more common BMPs. Significant additional information is available for numerous other BMPs in the LPSNRD Manual.

### 9.6.2 Silt Fence

The silt fence is a temporary linear sediment filter barrier constructed of synthetic filter fabric, posts and, depending upon the strength of the fabric used, wire fence for support. The filter fabric is stretched across and attached to supporting posts and entrenched. Figure 9-3 provides an example illustration of installation of a silt fence. Silt fences can be used in the following applications:

- for intercepting and detaining small amounts of sediment from disturbed areas during construction operations in order to prevent sediment from leaving the site,
- for decreasing the velocity of sheet flows and low-to-moderate level channel flows,
- in high-risk areas, such as those adjacent to streams, wetlands, reservoirs, lawns, etc.,
- as continual barriers at the toe of fill where ground slopes away,
- in short lengths at the toe of fill where ground slopes toward the fill,
- around median and yard inlets as applicable and
- behind curb and gutter to prevent silting of the pavement.

#### Use Limitations

- Since silt fences are among the most costly BMPs. If the size of the drainage areas is more than 1/4-acre per 100 feet of silt fence length, a different sediment and erosion control strategy should be investigated. The maximum gradient behind the barrier should be no more than 50% (2H:1V).
- Under no circumstances should silt fences be constructed in live streams or in swales or ditch lines where flows are likely to exceed 1 cubic foot per second.
- On steep slopes, care should be given to placing alignment of fence perpendicular to the general direction of the flow.

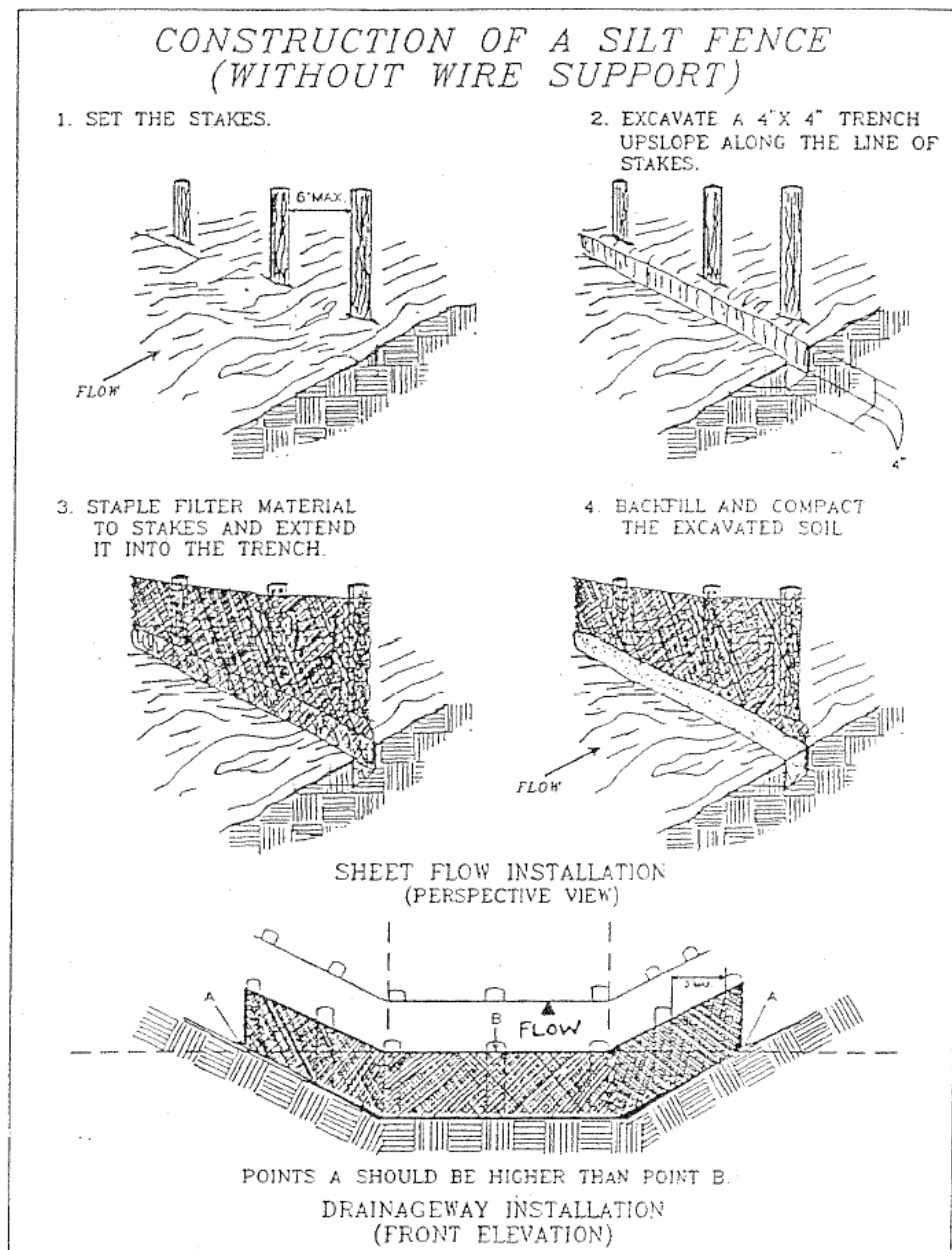
Erosion and Sediment Control Problem Areas	APPROPRIATE BEST MANAGEMENT PRACTICES												
	Silt Fence	Straw Bale Barrier	Inlet Protection	Outlet Protection	Diversion Dike	Check Dam	Construction Entrance	Temporary Vehicular Stream Crossing	Level Spreader	Temporary Sediment Trap	Temporary Sediment Basin	Temporary Seeding	Permanent Seeding
Manage Flow from Upgradient Areas					X								
Protect Adjacent Properties	X	X					X			X	X		
Waterways and Outlets	X	X	X	X		X		X					
Cut & Fill Slopes	X	X			X				X				
Temporary Stabilization												X	X
Permanent Stabilization													X

**Timing:** Provide a detailed schedule for installation of all erosion and sediment control measures.

**Inspection:** Provide an inspection schedule, responsible party, and inspection report form.

**Maintenance:** Provide a maintenance protocol for installed erosion and sediment control features.

**Figure 9-2 Appropriate Best Management Practices**



**Figure 9-3 Installation of Silt Fence**

Source: LPSNRD 1994.

Design Detailing

- No formal design is required.
- Silt fences are limited to situations in which only sheet or overland flows are expected. They normally cannot filter the volumes of water generated by channel flows, and many of the fabrics do not have sufficient structural strength to support the weight of water ponded behind the fence line. Their expected usable life is 5 months.

### Construction Guidelines

The following guidelines apply to silt fence materials:

- Silt fence shall be installed as per the manufacturer's recommendations.
- Synthetic filter fabric shall be a pervious sheet of propylene, nylon, polyester or ethylene yarn and shall be certified by the manufacturer or supplier as conforming to the following requirements as a minimum:
  - Filtering Efficiency Test - Silt Fence Filtering Efficiency (Source: FHWA Geotextile Engineering Manual, Appendix B).
  - Tensile Strength at 20% (max) Elongation
  - Test - ASTM D4595
  - Requirements reduced by 50% after 6 months.
  - Synthetic filter fabric shall contain ultraviolet ray inhibitors and stabilizers to provide a minimum of 6 months of expected usable construction life at a temperature range of 0 degrees F to 120 degrees F.
- The height of a silt fence shall not exceed 3 feet (higher fences may impound volumes of water sufficient to cause failure of the structure).
- When joints are necessary, filter cloth shall be spliced together only at a support post, with a minimum 6-inch overlap, and securely sealed.
- A trench shall be excavated approximately 4 inches wide and 4 inches deep along the line of posts and upslope from the barrier.
- The trench shall be backfilled and the soil compacted over the filter fabric.
- Silt fences should be removed when they have served their useful purpose, but not before the upslope area has been permanently stabilized.

### **9.6.3 Straw Bale Barrier**

Straw bale barriers are temporary sediment barriers consisting of a row of entrenched and anchored straw bales. Figure 9-4 illustrates installation of a straw bale barrier.

### Use Limitations

- Can be used where size of the drainage area is no greater than 1/4-acre per 100 feet of barrier length.
- Can be used where maximum slope gradient behind the barrier is no greater than 50%.
- Can be used in minor swales or ditches where the maximum contributing drainage area is no greater than 1 acre.
- Should not be used where effectiveness is required for more than 3 months.
- Should not be constructed in active streams or in swales where there is the possibility of a washout.
- Should be used only in areas of sheet flow or very low flow.
- Should not to be used where the control of sediment is critical or in high risk areas.
- Should not to be used where they cannot be entrenched as required and firmly anchored. Useful life of the baled straw barrier is relatively short and the barrier may have to be replaced one or more times during construction.

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### Design Detailing

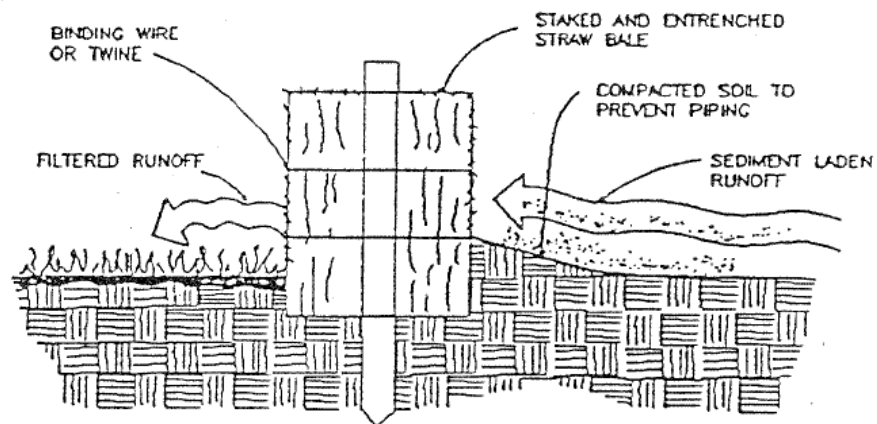
- No formal design is required.

### Construction Guidelines

#### Sheet Flow Applications:

- Bales shall be placed in a single row, lengthwise on the contour, with ends of adjacent bales tightly abutting.
- All bales shall be either wire-bound or string-tied. Straw bales shall be installed so that bindings are oriented around the sides rather than along the tops and bottoms of the bales (in order to prevent deterioration of bindings).

# STRAW BALE BARRIER



## PROPERLY INSTALLED STRAW BALE (CROSS SECTION)

1. EXCAVATE THE TRENCH.

2. PLACE AND STAKE STRAW BALES.

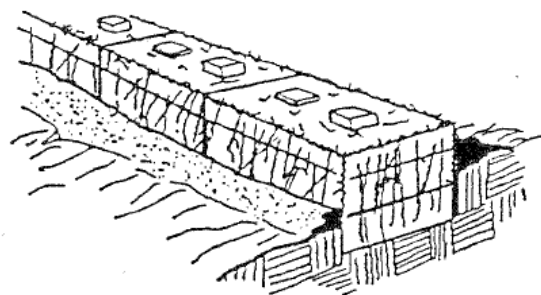
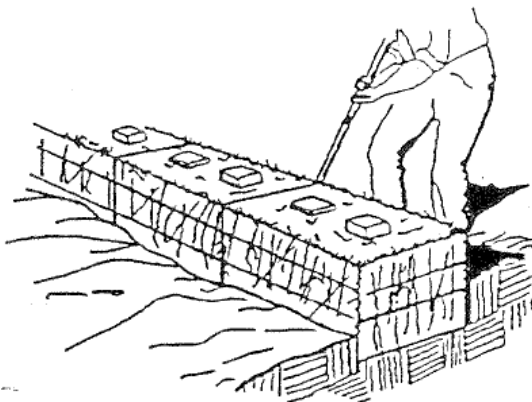
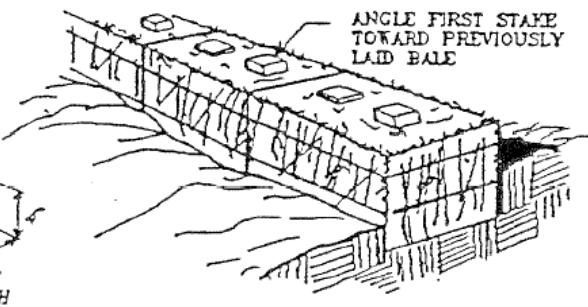
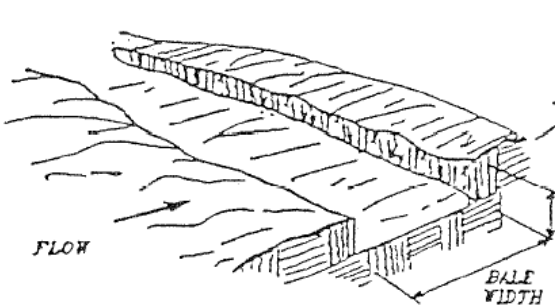


Figure 9-4 Installation of a Straw Bale Barrier

Source: LPSNRD 1994.

## Erosion And Sediment Control

- The barrier shall be entrenched and backfilled. A trench shall be excavated the width of a bale and the length of the proposed barrier to a minimum depth of 4 inches. After the bales are staked and chinked, the excavated soil shall be backfilled against the barrier. Backfill soil shall conform to the ground level on the downhill side and shall be built up to 4 inches against the uphill side of the barrier.
- Each bale shall be securely anchored by at least two stakes or re-bars driven toward the previously laid bale to force the bales together. Stakes or re-bars shall be driven into the ground to securely anchor the bales.
- The gaps between bales shall be chinked (filled by wedging) with straw to prevent water from escaping between the bales. Loose straw scattered over the area immediately uphill from a straw barrier tends to increase barrier efficiency.
- Inspection shall be frequent and repair or replacement shall be made promptly as needed.
- Straw bale barriers shall not be removed before the upslope areas have been permanently stabilized. It may be necessary to replace them as part of regular maintenance.

### Channel Flow Applications:

- Bales shall be placed in a single row, lengthwise, oriented perpendicular to the contour, with ends of adjacent bales tightly abutting one another.
- The requirements for installing a straw bale barrier for sheet flow applications apply, with the following addition: the barrier shall be extended to such a length that the bottoms of the end bales are higher in elevation than the top of the lowest middle bale to assure that sediment-laden runoff will flow over the barrier but not around it.

### 9.6.4 Storm Drain Inlet Protection

Storm drainage inlet protection is a sediment filter or an excavated impounding area around a storm drain drop inlet or curb inlet. Its purpose is to prevent sediment from entering storm drainage systems prior to permanent stabilization of the disturbed area. Different types of storm drain inlet protection are shown in Figures 9-5a through 9-5h.

#### Conditions Where Practice Applies

This practice shall be used where the drainage area to an inlet is disturbed, it is not possible to temporarily divert the storm drain outfall into a trapping device and watertight blocking of the inlets is not advisable. It is not to be used in place of sediment trapping devices. This may be used in conjunction with storm drain diversion to help prevent siltation of pipes installed with low slope angle. There are eight specific types of storm drain inlet protection practices that vary according to their function, location, drainage area and availability of materials:

1. Excavated Drop-Inlet Sediment Trap
2. Silt Fence Drop-Inlet Protection
3. Block and Gravel Drop-Inlet Sediment Filter
4. Sod Drop-Inlet Sediment Filter
5. Gravel and Wire Mesh Drop-Inlet Sediment Filter
6. Gravel Curb Inlet Sediment Filter
7. Curb Inlet Protection with Weir
8. Block and Gravel Curb Inlet Sediment Filter

#### Design Detailing

- The drainage area shall be no greater than 1 acre.
- The inlet protection device shall be constructed in a manner that will facilitate cleanout and disposal of trapped sediment and minimize interference with construction activities.
- The inlet protection device shall be constructed in such a manner that any resultant ponding of stormwater will not cause excessive inconvenience or damage to adjacent areas of structures.
- Design criteria more specific to each particular inlet protection device will be found within this specification.
-



- For the inlet protection devices which utilize stone as the chief ponding/filtering medium, a range of stone sizes is offered, 3/4" to 1-1/2" clean stone can be used. The designer should attempt to get the greatest amount of filtering action possible (by using smaller size stone), while not creating significant ponding problems.
- In all designs which utilize stone with a wire mesh support as a filtering mechanism, the stone can be completely wrapped with the wire mesh to improve stability and provide easier cleaning.
- Filter fabric may be added to any of the devices which utilize coarse aggregate stone to significantly enhance sediment removal. The fabric should be secured between the stone and the inlet (on wire mesh if present). As a result of the significant increase in filter efficiency provided by the fabric, a larger size of stone aggregate (1-1/2" to 2-1/2"), may be utilized with such a configuration. The larger stone will help keep larger sediment masses from clogging the fabric. Notably, significant ponding may occur at the inlet if the filter cloth is utilized in this manner.

### Construction Guidelines

1. Excavated Drop-Inlet Sediment Trap
  - a. The excavated trap shall be sized to provide a minimum storage capacity calculated at the rate of 900 c.f. per acre of drainage area. The trap shall be no less than one foot nor more than two feet deep measured from the top of the inlet structure. Side slopes shall be no steeper than 2:1.
  - b. The slope of the basin may vary to fit the drainage area and terrain. Observations must be made to check trap efficiency and modifications shall be made as necessary to ensure satisfactory trapping of sediment. Where an inlet is located to receive concentrated flows, the basin shall have a rectangular shape in a 2:1 (length/width) ratio, with the length oriented in the direction of flow.
  - c. Weep holes protected by fabric and stone shall be provided for draining the temporary pool.
  - d. Sediment shall be removed and the trap restored to its original dimensions when the sediment has accumulated to ½ the design depth of the trap. Removed sediment shall be deposited in a suitable manner such that it will not erode.
2. Silt Fence Drop-Inlet Protection
  - a. Silt fence shall be cut from a continuous roll to avoid joints.
  - b. Stakes shall be 2" x 4" wood or equivalent metal with a minimum length of three feet. Stakes shall be spaced evenly around the perimeter of the inlet a maximum of three feet apart and securely driven into the ground a minimum of 18 inches deep.
  - c. To provide needed stability to the installation, frame with 2" x 4" wood strips around the crest of the overflow area at a maximum of 1-1/2 feet above the drop inlet crest.
  - d. Place the bottom 12 inches of the fabric in a trench and backfill the trench with 12 inches of compacted soil.
  - e. Fasten fabric securely by staples or wire to the stakes and frame. Joints must be overlapped to the next stake.
  - f. It may be necessary to build a temporary dike on the downslope side of the structure to prevent bypass flow.
  - g. Remove sediment from the pool area as necessary or when it reaches half the height of the fabric, with care not to undercut or damage the fabric.
3. Block and Gravel Drop-Inlet Sediment Filter
  - a. Place concrete blocks lengthwise on their sides in a single row around the perimeter of the inlet, with the ends of adjacent blocks abutting. The height of the barrier can be varied, depending on the design needs, by stacking combinations of 4", 8" and 12" wide blocks. The barrier shall be at least 12 inches high and no greater than 24 inches high.
  - b. Wire mesh shall be placed over the outside vertical face of the concrete blocks to prevent stone from being washed through the holes in the blocks. Wire mesh with ½" opening shall be used.
  - c. Stone shall be piled against the wire to the top of the block barrier.
  - d. If the stone filter becomes clogged with sediment so that it no longer adequately performs its function, the stone must be pulled away from the blocks, cleaned and replaced.

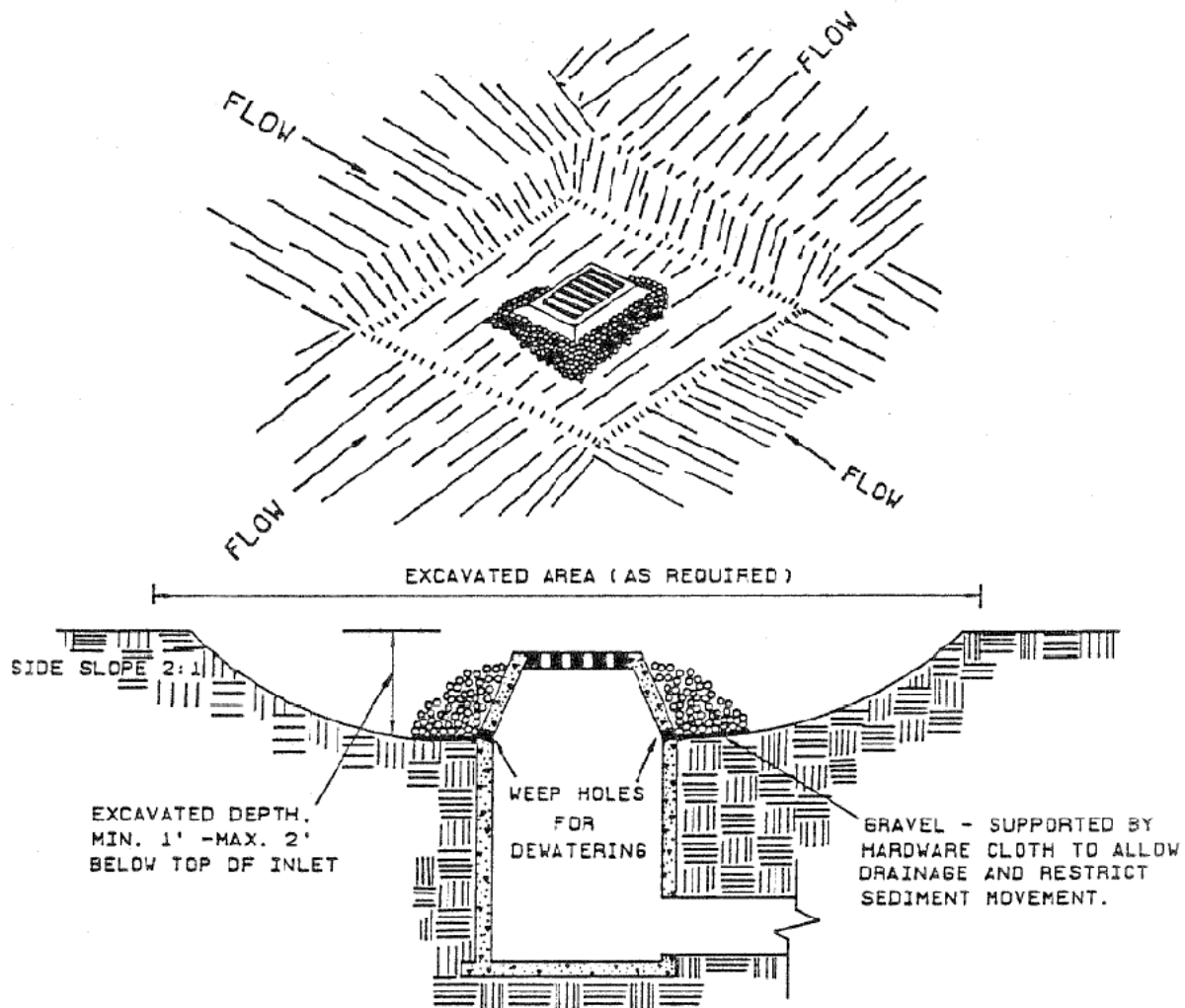
## Erosion And Sediment Control

4. Sod Drop-Inlet Sediment Filter
  - a. Soil shall be prepared and sod installed.
  - b. Sod shall be placed to form a turf mat covering the soil for a distance of 4 feet from each side of the inlet structure.
5. Gravel and Wire Mesh Drop-Inlet Sediment Filter
  - a. Wire mesh shall be laid over the drop inlet so that the wire extends a minimum of 1 foot beyond each side of the inlet structure. Wire mesh with  $\frac{1}{2}$ " openings shall be used. If more than one strip of mesh is necessary, the strips shall be overlapped a minimum of 6 inches.
  - b. Course aggregate shall be placed over the wire mesh with a minimum depth of 12 inches over the entire inlet opening. The stone shall extend beyond the inlet opening at least 18 inches on all sides.
  - c. If the stone filter becomes clogged with sediment so that it no longer adequately performs its function, the stone must be pulled away from the inlet, cleaned and replaced.
  - d. This type of protection may not be used where the overflow may endanger an exposed fill slope.
6. Gravel Curb Inlet Sediment Filter
  - a. Wire mesh with  $\frac{1}{2}$ " openings shall be placed over the curb inlet opening so that at least 12 inches of wire extends across the inlet cover and at least 12 inches of wire extends across the concrete gutter from the inlet opening.
  - b. Stone shall be piled against the wire so as to anchor it against the gutter and inlet cover and to cover the inlet opening completely.
  - c. If the stone filter becomes clogged with sediment so that it no longer adequately performs its function, the stone must be pulled away from the inlet, cleaned and replaced.
7. Curb Inlet Protection with Weir
  - a. Attach a continuous piece of wire mesh (30" minimum width x inlet throat length plus 4 feet) to the 2" x 4" wooden weir (with a total length of inlet throat length plus 2 feet). Wood shall be exterior type construction lumber.
  - b. Place a piece of filter fabric the same dimensions as the wire mesh over the wire mesh and securely attach to the 2" x 4" weir.
  - c. Securely nail the 2" x 4" weir to the 9" long vertical spacers which are to be located between the weir and inlet face at a maximum 6 foot spacing.
  - d. Place the assembly against the inlet throat and nail 2 foot minimum lengths of 2" x 4" lumber to the top of the weir at spacer locations. These anchors shall extend across the inlet tops and be held in place by sandbags or alternate weight.
  - e. The assembly shall be placed so that the end spacers are a minimum of 1 foot beyond both ends of the throat opening.
  - f. Form the wire mesh and filter fabric to the concrete gutter and against the face of the curb on both sides of the inlet. Place coarse aggregate over the wire mesh and filter fabric in such a manner as to prevent water from entering the inlet under or around the filter cloth.
  - g. This type of protection must be inspected frequently and the filter cloth and stone replaced when clogged with sediment.
  - h. Assure that storm flow does not bypass inlet by installing temporary earth dikes directing flow into inlet.
8. Block and Gravel Curb Inlet Sediment Filter
  - a. Two concrete blocks shall be placed on their sides abutting the curb at either side of the inlet opening. A 2" x 4" stud shall be cut and placed through the outer holes of each spacer block to help keep the front blocks in place.
  - b. Concrete blocks shall be placed on their sides across the front of the inlet and abutting the spacer blocks.
  - c. Wire mesh with  $\frac{1}{2}$ " openings shall be placed over the outside vertical face of the concrete blocks to prevent stone from being washed through the holes in the blocks.
  - d. Coarse aggregate shall be piled against the wire to the top of the barrier.
  - e. If the stone filter becomes clogged with sediment so that it no longer adequately performs its function, the stone must be pulled away from the blocks, cleaned and replaced.

Maintenance

1. Structures shall be inspected after each rain and repairs made as necessary.
2. Structures shall be removed and the area stabilized when the remaining drainage area has been properly stabilized.

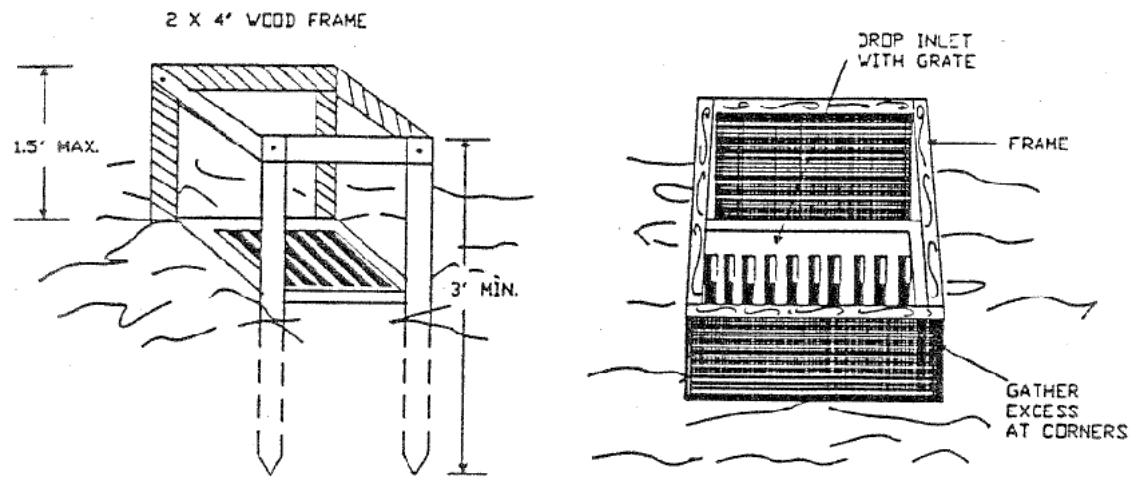
## EXCAVATED DROP INLET SEDIMENT TRAP



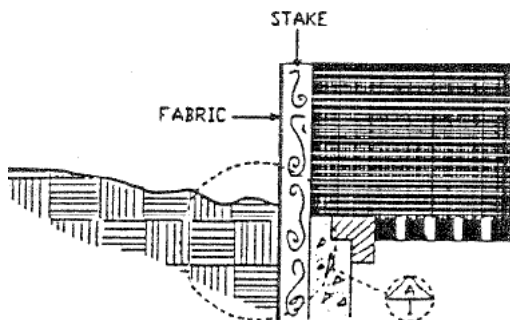
THIS METHOD OF INLET PROTECTION IS APPLICABLE WHERE HEAVY FLOWS ARE EXPECTED AND WHERE AN OVERFLOW CAPABILITY AND EASE OF MAINTENANCE ARE DESIRABLE.

Figure 9-5a Excavated Drop Inlet Sediment Trap

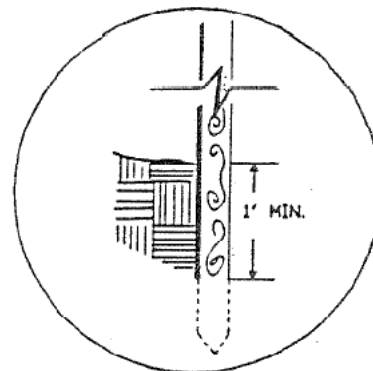
# *SILT FENCE DROP INLET PROTECTION*



PERSPECTIVE VIEWS



ELEVATION OF STAKE AND FABRIC ORIENTATION



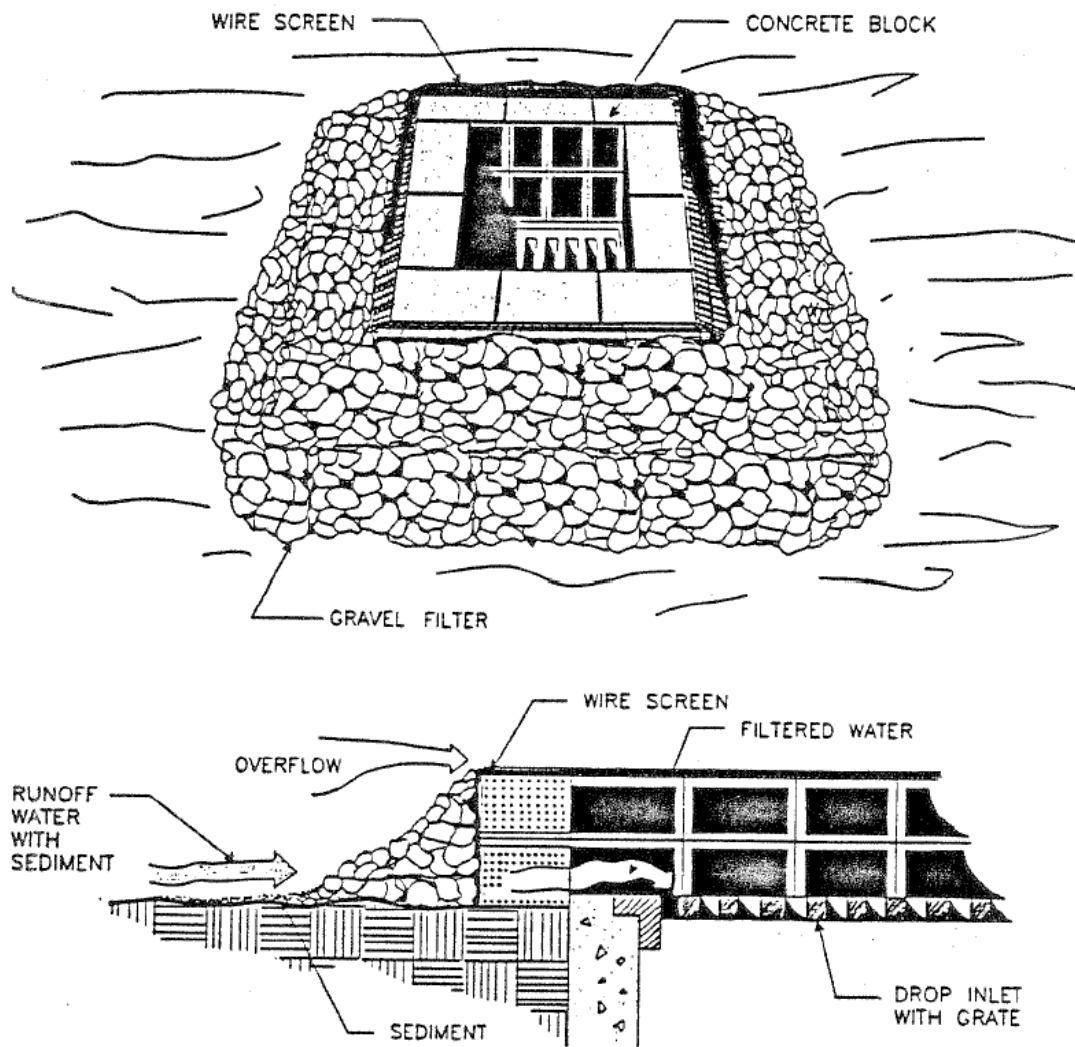
DETAIL A

## SPECIFIC APPLICATION

THIS METHOD OF INLET PROTECTION IS APPLICABLE WHERE THE INLET DRAINS A RELATIVELY FLAT AREA (SLOPE NO GREATER THAN 5%) WHERE THE INLET SHEET OR OVERLAND FLOWS (NOT EXCEEDING 1 C.F.S.) ARE TYPICAL. THE METHOD SHALL NOT APPLY TO INLETS RECEIVING CONCENTRATED FLOWS, SUCH AS IN STREET OR HIGHWAY MEDIANS.

Figure 9-5b Silt Fence Drop Inlet Protection

## *BLOCK AND GRAVEL DROP INLET SEDIMENT FILTER*

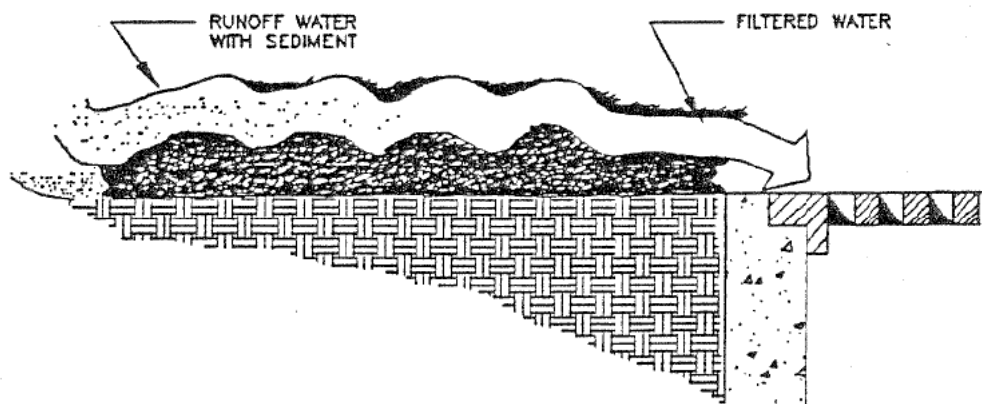
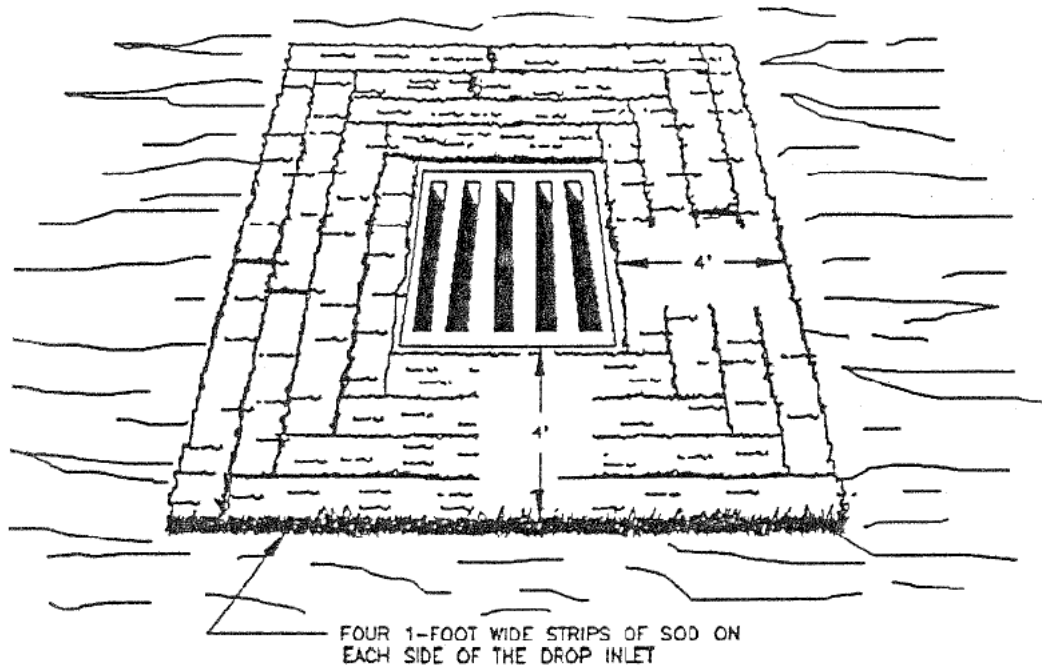


### SPECIFIC APPLICATION

THIS METHOD OF INLET PROTECTION IS APPLICABLE WHERE HEAVY FLOWS ARE EXPECTED AND WHERE AN OVERFLOW CAPACITY IS NECESSARY TO PREVENT EXCESSIVE PONDING AROUND THE STRUCTURE.

Figure 9-5c Block And Gravel Drop Inlet Sediment Filter

## *SOD DROP INLET SEDIMENT FILTER*

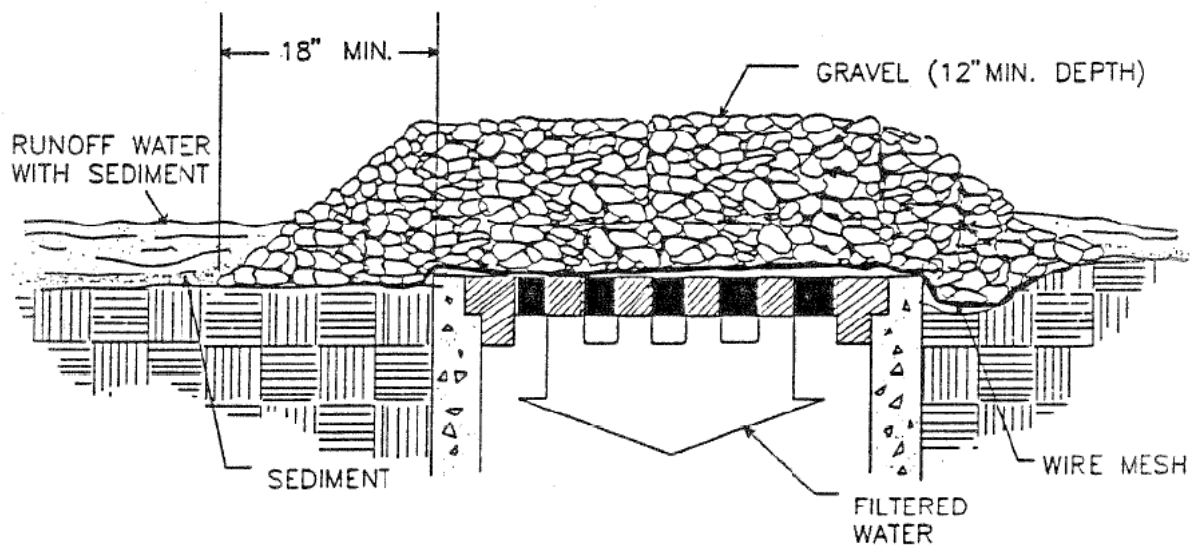


### SPECIFIC APPLICATION

THIS METHOD OF INLET PROTECTION IS APPLICABLE ONLY AT THE TIME OF PERMANENT SEEDING, TO PROTECT THE INLET FROM SEDIMENT AND MULCH MATERIAL UNTIL PERMANENT VEGETATION HAS BECOME ESTABLISHED.

Figure 9-5d Sod Drop Inlet Sediment Filter

## GRAVEL AND WIRE MESH DROP INLET SEDIMENT FILTER



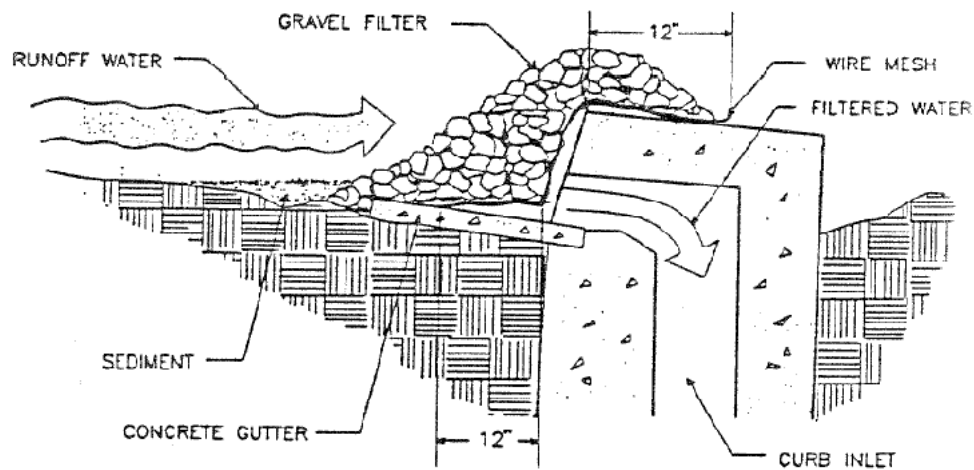
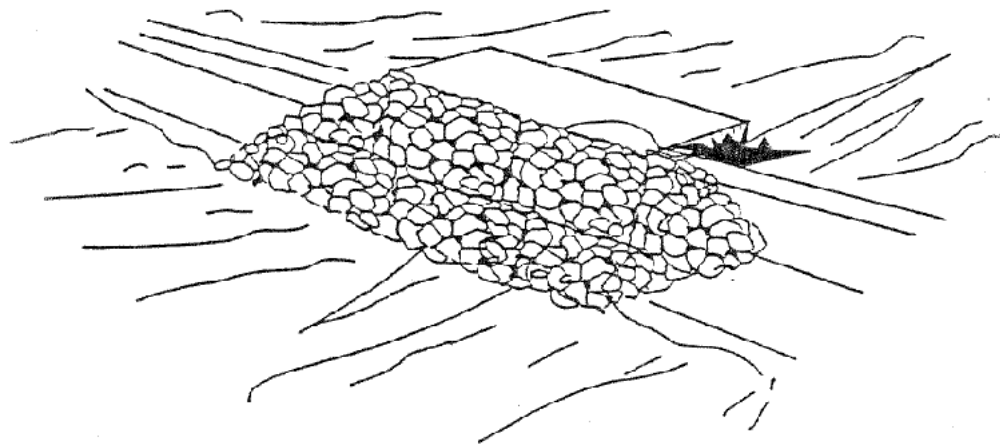
### SPECIFIC APPLICATION

THIS METHOD OF INLET PROTECTION IS APPLICABLE WHERE HEAVY CONCENTRATED FLOWS ARE EXPECTED, BUT NOT WHERE PONDING AROUND THE STRUCTURE MIGHT CAUSE EXCESSIVE INCONVENIENCE OR DAMAGE TO ADJACENT STRUCTURES AND UNPROTECTED AREAS.

Figure 9-5e Gravel And Wire Mesh Drop Inlet Sediment Filter



## GRAVEL CURB INLET SEDIMENT FILTER



### SPECIFIC APPLICATION

THIS METHOD OF INLET PROTECTION IS APPLICABLE AT CURB INLETS WHERE PONDING IN FRONT OF THE STRUCTURE IS NOT LIKELY TO CAUSE INCONVENIENCE OR DAMAGE TO ADJACENT STRUCTURES AND UNPROTECTED AREAS.

Figure 9-5f Gravel Curb Inlet Sediment Filter

# *CURB INLET PROTECTION WITH 2-INCH X 4-INCH WOODEN WEIR*

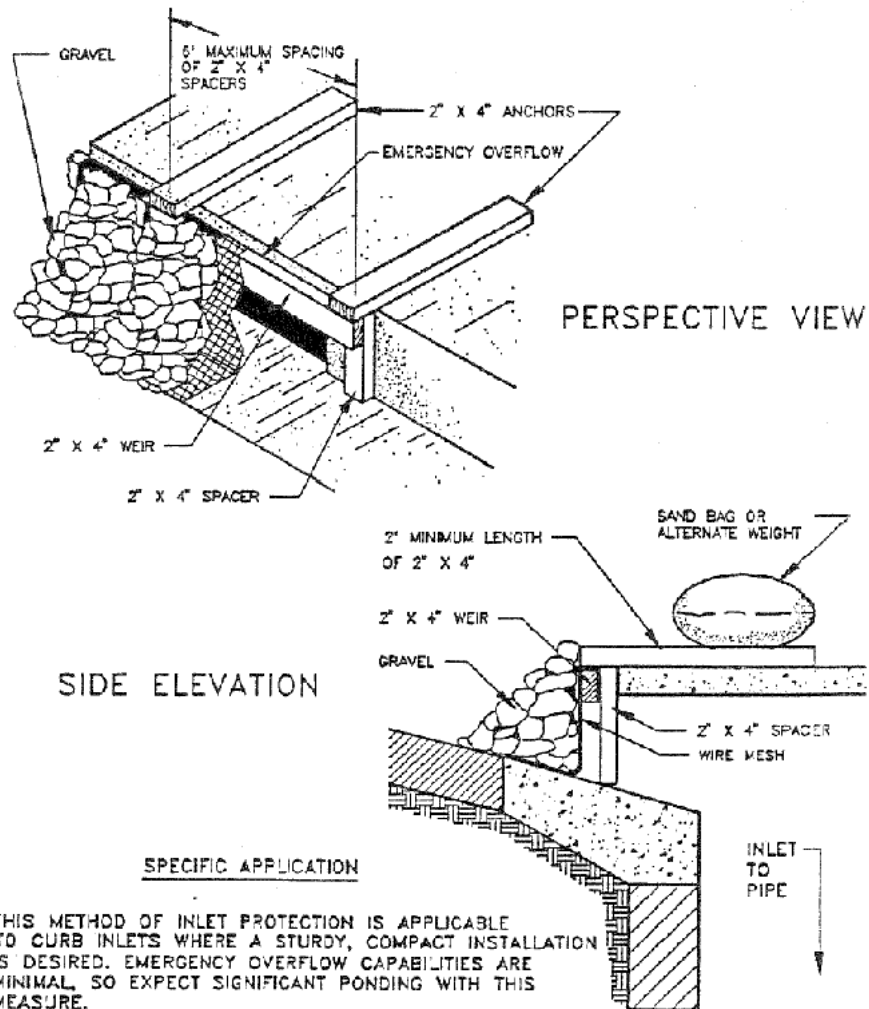
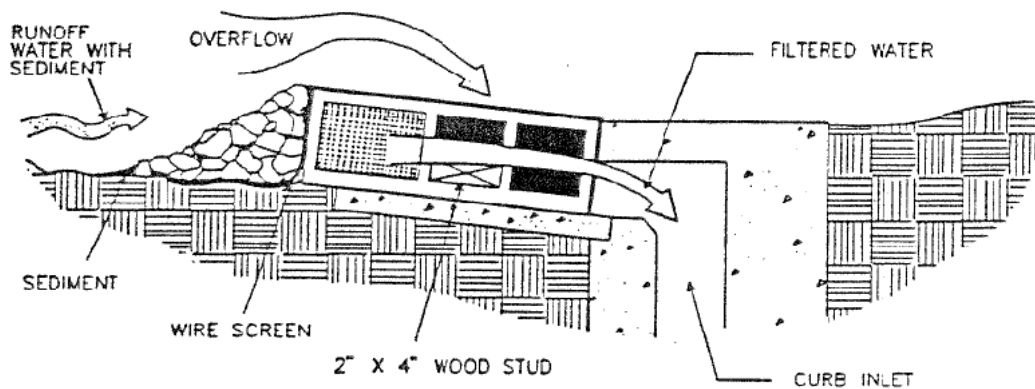
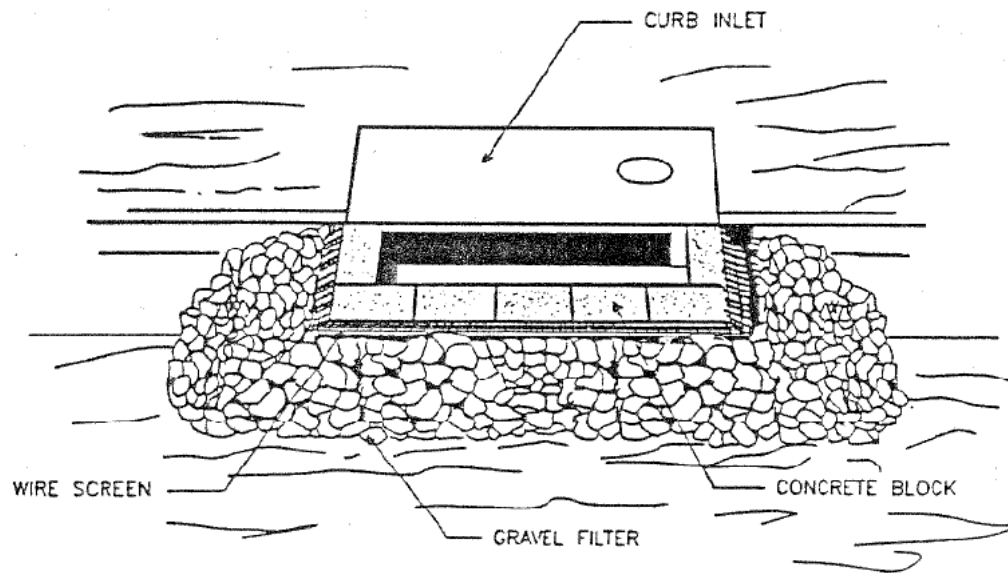


Figure 9-5g Curb Inlet Protection With 2" x 4" Wooden Weir

## *BLOCK & GRAVEL CURB INLET SEDIMENT FILTER*



### SPECIAL APPLICATION

THIS METHOD OF INLET PROTECTION IS APPLICABLE AT CURB INLETS WHERE AN OVERFLOW CAPABILITY IS NECESSARY TO PREVENT EXCESSIVE PONDING IN FRONT OF THE STRUCTURE.

Figure 9-5h Block And Gravel Curb Inlet Sediment Filter

### **9.6.5 Outlet Protection**

The outlets of pipes and structurally lined channels are points of critical erosion potential. To prevent scour at storm-water outlets, a flow transition structure is needed which will absorb the initial impact of the flow and reduce the flow velocity to a level which will not erode the receiving channel or area.

The most commonly used device for outlet protection is a structurally lined apron. These aprons are generally lined with riprap, grouted riprap or concrete. Where flow is excessive for the economical use of an apron, excavated stilling basins or other alternative structures may be used (Figure 9-6). Examples of other aprons described in Chapter 7 are shown in Figure 9-7.

#### Design Detailing

Table 9-1 gives the permissible velocity recommendations for the determination of outlet protection needs. Additional design detailing can be found in Chapter 7 of this manual or in the following sources.

- Hydraulic Design of Energy Dissipators for Culverts and Channels, Hydraulic Engineering Circular No. 14, U.S. Department of Transportation, Federal Highway Administration.
- Hydraulic Design of Stilling Basins and Energy Dissipators, Engineering Monograph No. 25, U.S. Department of the Interior, Bureau of Reclamation.

**Table 9-1 Permissible Velocities For Grass And Earth Lined Channels****Grass-Lined Channels**

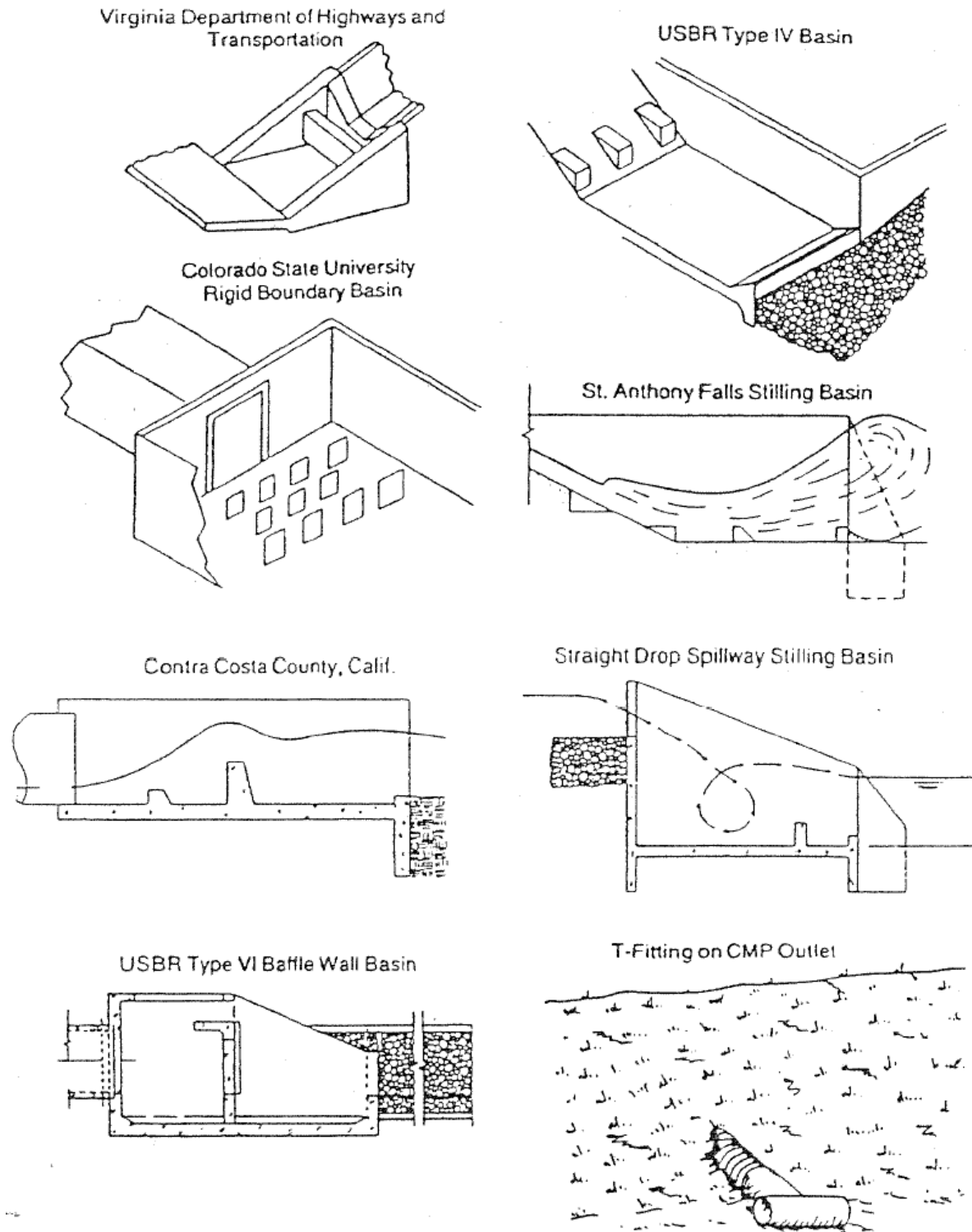
<u>Channel Slope</u>	<u>Lining</u>	<u>Permissible Velocity*</u>
0.5%	Bermuda grass	6 ft/s
	Reed canarygrass	5 ft/s
	Tall fescue	5 ft/s
	Kentucky bluegrass	5 ft/s
	Grass-legume mixture	4 ft/s
	Red fescue	4 ft/s
	Redtop	4 ft/s
	Sericea lespedeza	4 ft/s
	Annual lespedeza	4 ft/s
5-10%	Bermudagrass	5 ft/s
	Reed canarygrass	4 ft/s
	Tall fescue	4 ft/s
	Kentucky bluegrass	4 ft/s
	Grass-legume mixture	3 ft/s
>10%	Bermudagrass	4 ft/s
	Reed canarygrass	3 ft/s
	Tall fescue	3 ft/s
	Kentucky bluegrass	3 ft/s

**Earth Linings**

<u>Soil Types</u>	<u>Permissible Velocity<sup>1</sup></u>
Fine Sand (noncolloidal)	2.5 ft/s
Sandy Loam (noncolloidal)	2.5 ft/s
Silt Loam (noncolloidal)	3.0 ft/s
Ordinary Firm Loam	3.5 ft/s
Fine Gravel	5.0 ft/s
Stiff Clay (very colloidal)	5.0 ft/s
Graded, Loam to Cobbles (noncolloidal)	5.0 ft/s
Graded, Silt to Cobbles (colloidal)	5.5 ft/s
Alluvial Silts (noncolloidal)	3.5 ft/s
Alluvial Silts (colloidal)	5.0 ft/s
Coarse Gravel (noncolloidal)	6.0 ft/s
Cobbles and Shingles	5.5 ft/s
Shales and Hard Pans	6.0 ft/s

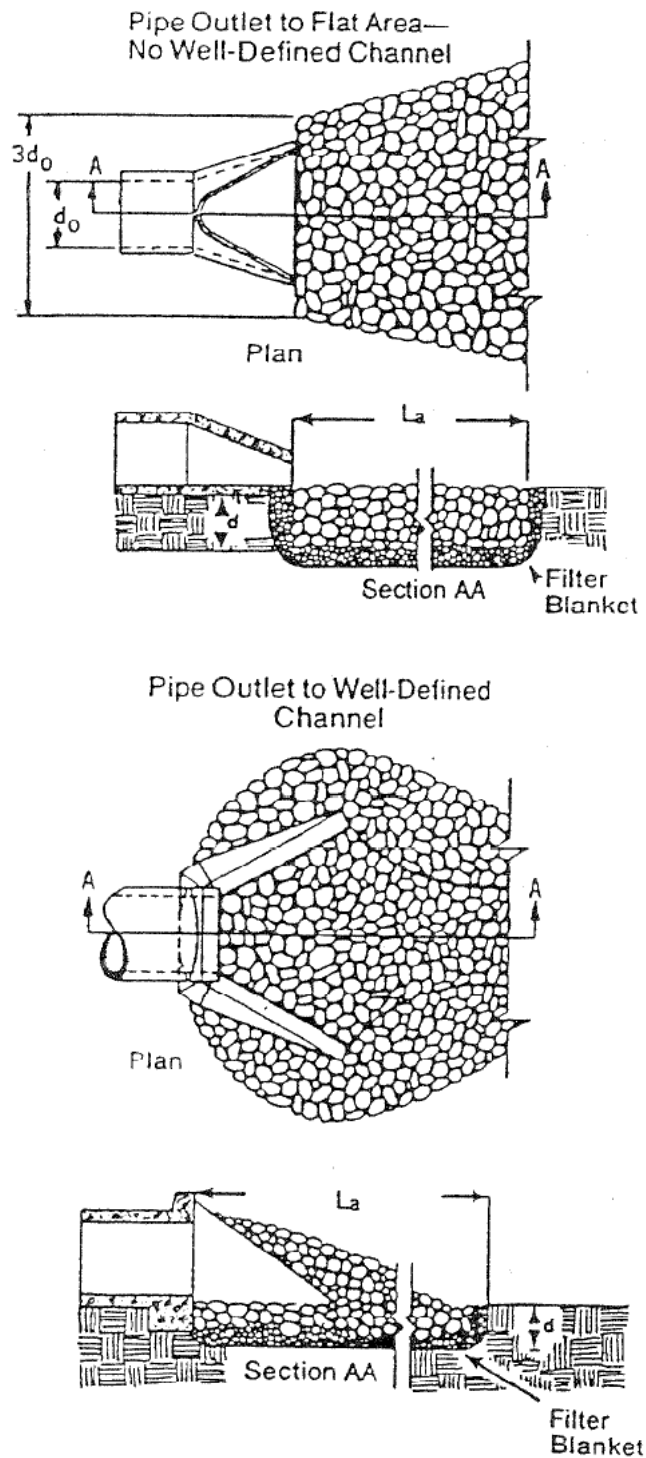
<sup>1</sup>For highly erodible soils, decrease permissible velocities by 25%

\*Source: Soil and Water Conservation Engineering, Schwab, et. al. and American Society of Civil Engineers



**Figure 9-7 Structures Used For Outlet Protection By Dissipating Energy**

Source: North Carolina Erosion And Sediment Control Manual, 1988.



**Figure 9-6 Outlet Protection**

Source: North Carolina Erosion And Sediment Control Manual, 1988.

#### 9.6.6 Diversion

A diversion is a channel constructed across a slope with a supporting ridge on the lower side for the purpose of reduc-

## Erosion And Sediment Control

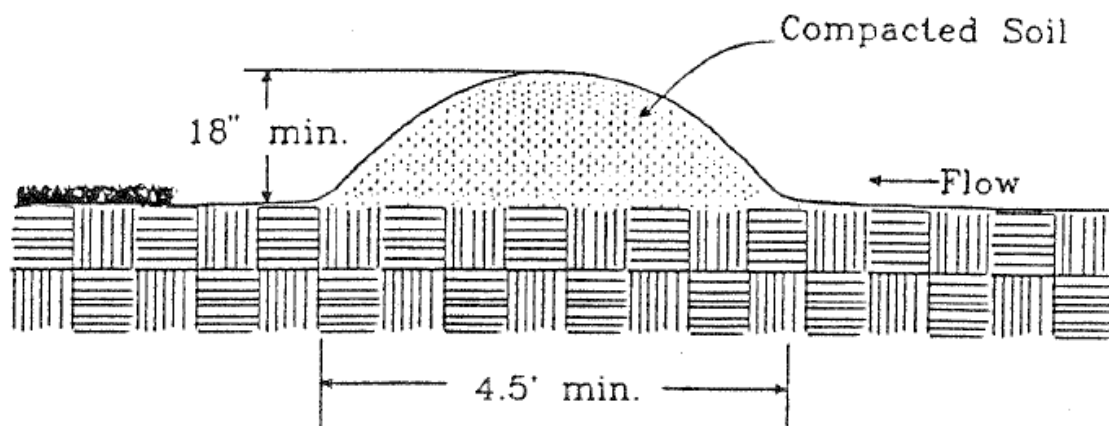
ing the slope length and intercepting and diverting stormwater runoff to stabilized outlets at non-erosive velocities. Diversions are used where:

- runoff from higher areas may damage property, cause erosion, or interfere with the establishment of vegetation on lower areas;
- surface and/or shallow subsurface flow is damaging upland slopes; or
- slope length needs reduction to minimize soil loss.

Figure 9-8 and 9-9 illustrate the use of diversions.

### Design Detailing

- In most instances, diversions are constructed using a standard design or sized for site flow conditions.
- Location - Diversion location should be determined by considering outlet conditions, topography, land use, soil type, length of slope, seepage planes (where seepage is a problem) and the development layout.
- Capacity - The diversion channel shall have a minimum capacity to carry the runoff expected from a minimum of 2-year frequency storm with a freeboard of at least 0.3 foot. Diversions designed to protect homes, schools, industrial buildings, roads, parking lots and comparable high-risk areas and those designed to function in connection with other structures shall have sufficient capacity to carry peak runoff expected from a storm frequency consistent with the hazard involved.
- Channel Design - The diversion channel may be parabolic, trapezoidal or V-shaped.
- Ridge Design - The supporting ridge cross-section shall meet the following criteria:
  - The side slopes shall be no steeper than (2H:1V).
  - The width at the design water elevation shall be a minimum of 4 feet.
  - The minimum freeboard shall be 0.3 feet.
  - Include a 10% factor to allow for anticipated settlement.



**Figure 9-8 Use Of Temporary Diversions**

re 9-

Source: LPSNRD 1994.